



# Laboratory Study of Polychlorinated Biphenyls (PCBs) in Buildings

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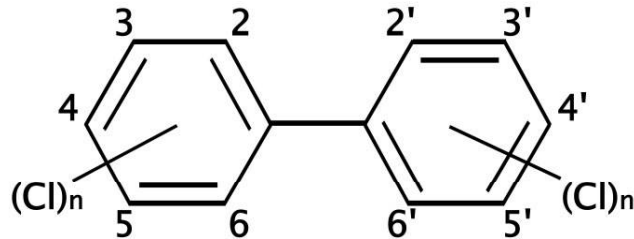
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# Outline

- ❖ Background
- ❖ Research Approaches
- ❖ Major Findings
- ❖ Limitations & Future Work

## Background – What are PCBs?

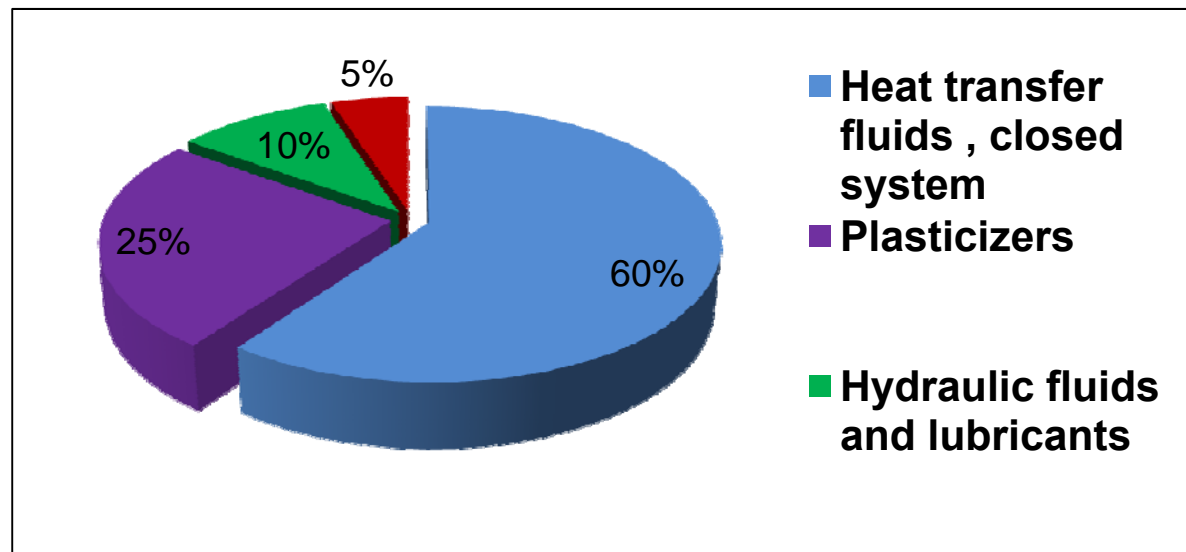


Polychlorinated Biphenyl ( $n = 1$  to  $5$ )

- ❖ Synthesized organic chemicals known as chlorinated hydrocarbons
- ❖ 209 PCB congeners
- ❖ Common trade name – Aroclor
- ❖ Among the most persistent, non-natural chemicals
- ❖ From thin, light-colored liquids to yellow or black waxy solids and may exist as a vapor in air
- ❖ Non-flammability, chemical stability, high boiling point, and electrical insulator
- ❖ Manufactured in US for commercial use from 1929 until banned in 1978

## Background – PCB Usage

- ❖ Electrical, heat transfer, capacitors, fluorescent light ballasts, and hydraulic equipment
- ❖ Construction materials – caulking, other sealants, adhesives, paints, floor finishes, plastics, and rubber products, etc
- ❖ In pigments, dyes, and carbonless copy paper

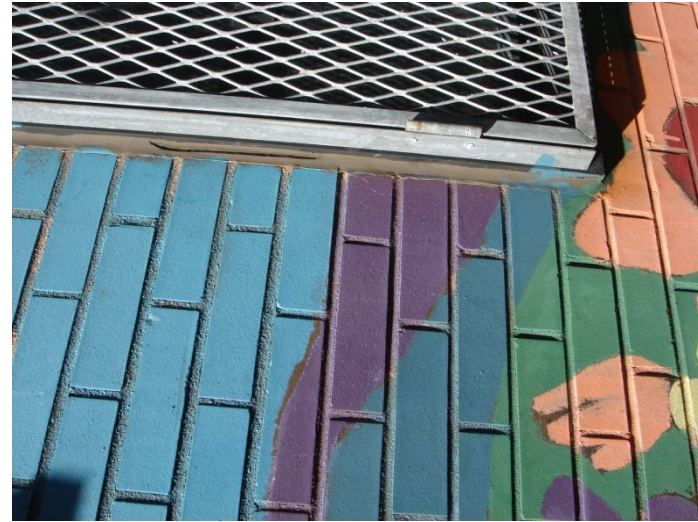


EIP Associates, 1997

# Background – PCB Usage



**PCB caulk in masonry joints**



**PCB caulk along window**



**PCB in fluorescent light ballasts**

# Background – Exposure to PCBs

## Routes of Exposure

- ❖ Inhalation – air, dust
- ❖ Ingestion – food consumption, drinking water, breastfeeding
- ❖ Dermal - skin contact, product use, surface soils



# Background – Adverse Health Effects

## Potential Harmful Health Effects

- ❖ Cause cancer in animals
- ❖ Serious non-cancer health effects in animals and/or humans
  - ✓ Immune Effects
  - ✓ Reproductive Effects
  - ✓ Neurological Effects
  - ✓ Endocrine Effects
  - ✓ Dermal and ocular effects in monkeys and humans,
  - ✓ Liver toxicity
  - ✓ Elevations in blood pressure, serum triglyceride, and serum cholesterol with increasing serum levels of PCBs in humans

# Background – Studies

## PCB Research

- ❖ Field measurements conducted in Europe and North America have shown that PCB-containing caulk and sealant can be a significant source of PCBs in buildings
- ❖ Aged or burned-out fluorescent lights ballast may emit high concentrations of PCBs
- ❖ Health effects research

# Background – Solutions

## PCB Mitigation Methods

- ❖ Source removal
  - ✓ Physical source removal, such as bulk removal, blasting, cutting
  - ✓ Chemical degradation
  - ✓ Chemical extraction and cleaning
- ❖ Source modification
  - ✓ Encapsulation
  - ✓ Physical Barriers
- ❖ Management solutions
  - ✓ Administrative controls
  - ✓ Ventilation
  - ✓ Air cleaning
  - ✓ Hazardous waste management

# Objectives & Tasks

## Objectives

- ❖ Characterize PCB sources in schools, including secondary sources, to support exposure/risk assessment for PCBs in schools
- ❖ Evaluate mitigation methods to support risk management decision-making for PCBs in schools

## Tasks

- ❖ Task 1. Emissions from selected primary sources
- ❖ Task 2. Transport to building materials and settled dust
- ❖ Task 3. Evaluation of the encapsulation method
- ❖ Task 4. Evaluation of an on-site PCB destruction method



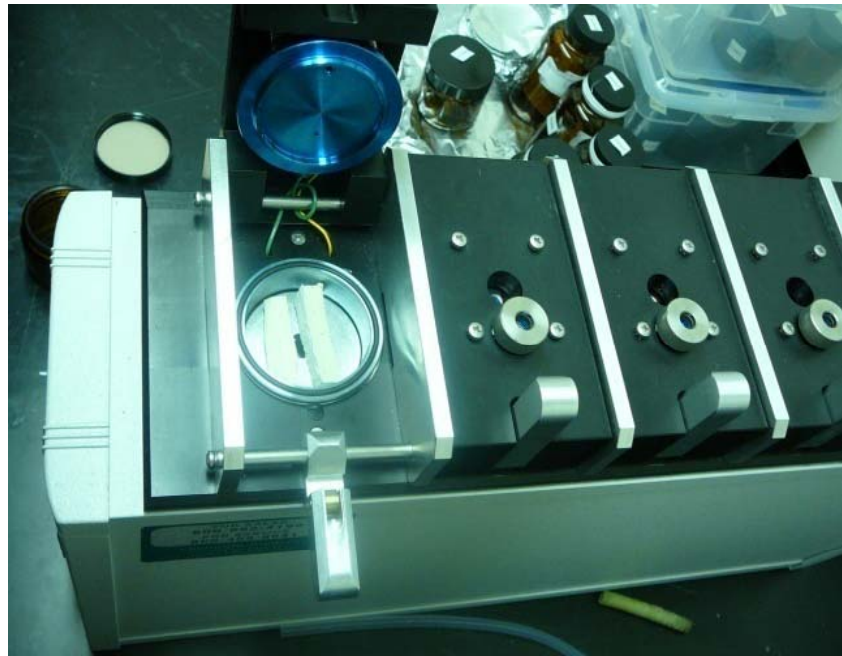
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# Source Emissions

## Caulk Testing

- ❖ Tested 12 samples of caulk from contaminated buildings
- ❖ 11 contained Aroclor 1254; one contained 1260
- ❖ PCB content from <10 to 136,000 ppm
- ❖ Emission tests performed in micro chambers



# Source Emissions

## Light Ballast Testing

- ❖ 19 light ballasts, representing 13 brands and models
  - ✓ No “PCB Free” label
  - ✓ No visible fluid leakage
- ❖ Opened 3 ballasts; the fluids in the capacitors were Aroclor 1242
- ❖ Emission tests in 53-liter chambers
  - ✓ Without electrical load
  - ✓ With electrical load
  - ✓ Different temperatures



**Light Ballast tested**

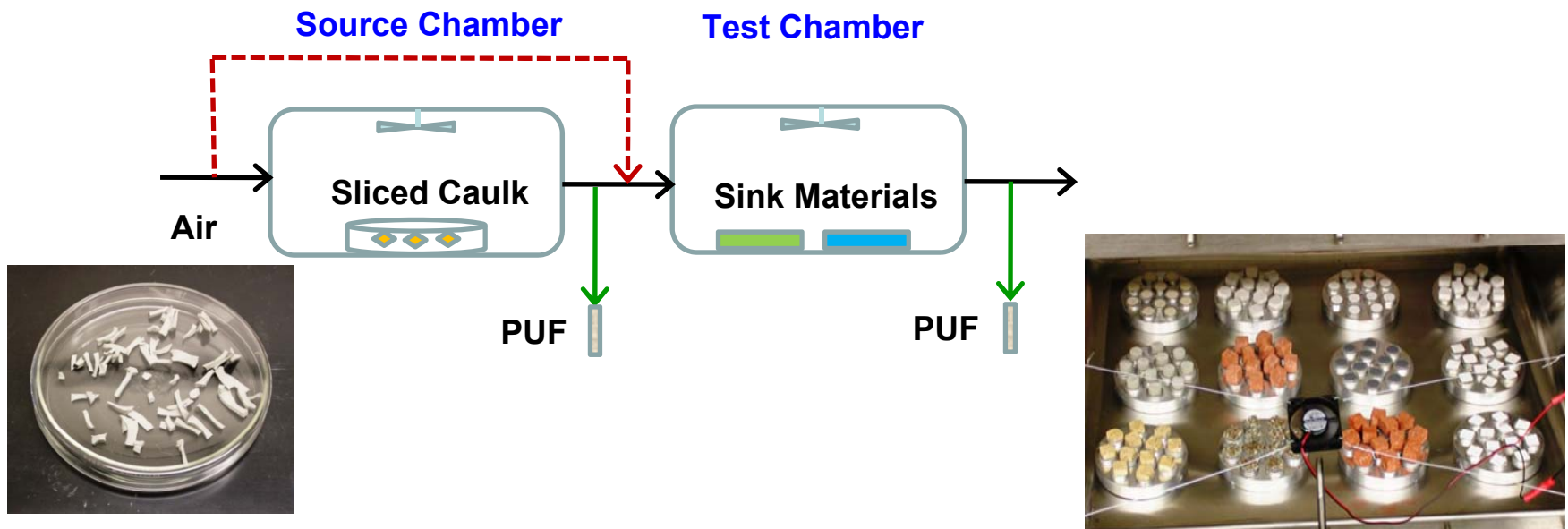


**Small chamber picture**

# PCB Transport – Building Materials as Sink

## Sink Tests

- ❖ Two 53-L chambers in series
- ❖ Building materials were tested as small pellets
- ❖ Pellets were removed from chamber at different times to determine the PCB content
- ❖ PCB concentrations in chamber air were monitored



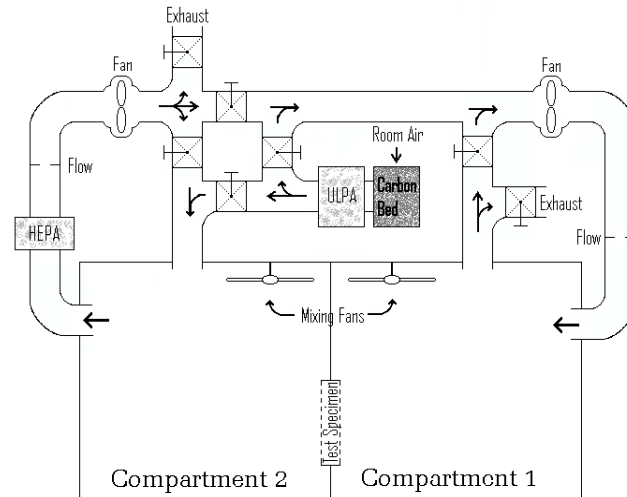
**Caulk as the source of Aroclor 1254**

**Materials in the Test Chamber**

# PCB Transport – Settled Dust as a PCB Sink



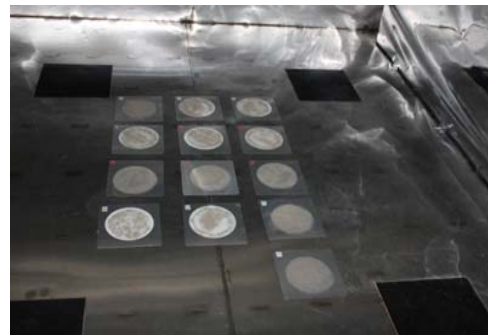
**30-m<sup>3</sup> Environmental Chamber**



**Schematic of the Chamber System**



**Loading dust to test panels**



**Test panels on the chamber floor**



# Evaluation of the Encapsulation Method

- ❖ Conduct sink tests to determine the encapsulants' resistance to PCB sorption; results were used to:
  - Rank the encapsulants based on experimentally determined sorption concentrations
  - Estimate the partition and diffusion coefficients
- ❖ Evaluate the performance using wipe sampling
  - Accelerated aging
  - "Natural" aging
- ❖ Use a barrier model to evaluate the performances of encapsulants in detail
  - Understand the behavior of encapsulated PCB sources
  - Rank encapsulants based on specific performance criteria



# Evaluation of the Encapsulation Method

## Ten Encapsulants Tested

Short Name	Binder or Base Material	Uses
Acrylate-waterborne	Modified waterborne acrylate	concrete and masonry
Acrylic-latex enamel	Acrylic latex	wood, metal , drywall, interior/exterior, etc.
Acrylic-solvent	Solvent acrylic	concrete, cider block, brick, etc.
Epoxy-no solvent	Solvent-free epoxy	concrete, steel
Epoxy-low VOC	Low-VOC polyamide epoxy	steel, concrete
Epoxy-waterborne	Waterborne modified polyamine epoxy	cementations and other porous substrates
Lacquer primer	Talc and quartz + solvents	metals, interior/exterior
Oil enamel	Oil-based enamel	wood, metal , drywall, interior/exterior, etc.
Polyurea elastomer	Polyurea	self-leveling base coat; deck, crack and floor repair
Polyurethane	Polyurethane	wood

# Evaluation of the Encapsulation Method



**QUV Accelerated Weathering Chamber,  
UVA irradiance: 0.89 W/(m<sup>2</sup>·nm)  
Temperature: 60 °C**

**Encapsulated source panels**

# Evaluation of the Activated Metal Treatment System (AMTS)

- ❖ Developed by NASA and University of Central Florida
- ❖ Extracting PCBs from the source into the AMTS paste
- ❖ Eliminating PCBs by dechlorination
- ❖ Reaction Mechanism

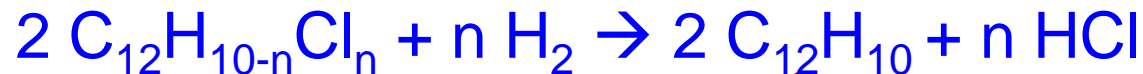
- **Generation of hydrogen**

Magnesium (reducing agent)



- **Dechlorination**

proton donor (alcohol, acid, or water)



PCB

Biphenyl

# Evaluation of the Activated Metal Treatment System (AMTS)

## Formulation of AMTS Paste

Component	Purpose	Active Paste	Inactive Paste
Ethanol	Solvent	√	√
Glacial acetic acid	pH adjusting	√	
Limonene	Co-solvent	√	√
Calcium Stearate	Defoamer	√	√
Carbomax PEG 8000	Surface lubricating	√	√
Glycerin (glycerol)	Thickener/reducing flammability	√	√
Sodium Polyacrylate(5'100)	Adsorbent	√	√
Magnesium Powder	Reducing agent	√	

**The quantity of each component and preparation procedure are proprietary information owned by NASA.**



# Evaluation of the Activated Metal Treatment System (AMTS)

## Materials Tested

Material Category	Material Description
Coating material	Alkyd paint
	Oil-based primer
	Epoxy coating
Caulk	Field caulk 1
	Field caulk 2
	Lab-mixed polysulfide caulk
Concrete	Lab-made concrete "buttons"

# Evaluation of the Activated Metal Treatment System (AMTS)

Inactive

Active



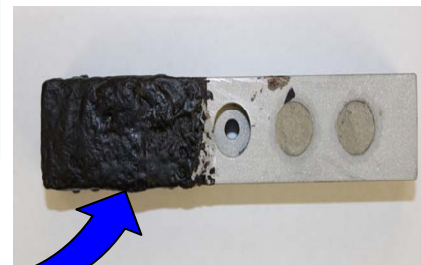
**AMTS Paste**



**Before treatment**



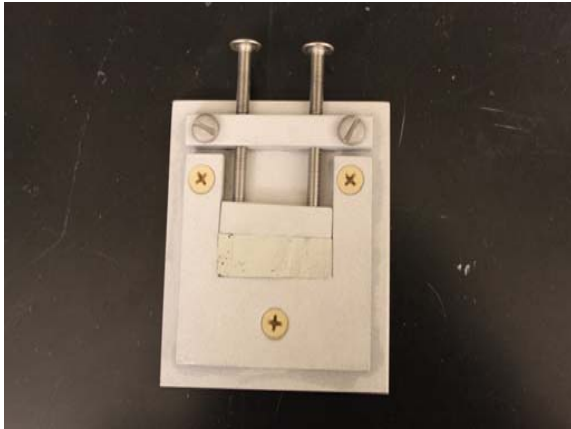
**Covered with  
coating  
material**



**Testing of Concrete**

# Evaluation of the Activated Metal Treatment System (AMTS)

1. Place caulk into sample holder



3. Apply the cover coat



2. Covered with active paste



4. Cut treated caulk for extraction



# Analytical Protocols

## ❖ Extraction

- Sonication – Modified EPA Method 3550B
- Soxhlet – Modified EPA Method 3541

## ❖ Analysis

- GC/MS or GC/ECD – Modified EPA Method 8082A and 680
- 3 internal standards and 3 recovery check standards
- 10 selected PCB congeners as target analytes

## ❖ Approved Category II QAPP

**CTC Combi PAL with Agilent  
6890/5973 GC/ MS/ ECD**





# Outline

- ❖ Background
- ❖ Research Approaches
- ❖ Major Findings**
- ❖ Limitations & Future Work

# Major Findings

- ❖ Four peer-reviewed EPA reports will be published
  - Emissions from selected primary sources
  - Transport to building materials and settled dust
  - Evaluation of the encapsulation method
  - Evaluation of an on-site PCB destruction method
- ❖ One literature review by an EPA contractor
  - Remediation methods for PCBs in buildings

# Major Findings

## ❖ Emissions from Caulk

- The PCB emissions from caulk favor volatile congeners
- The emission factor of a congener is determined by its content and vapor pressure
- Congener emissions from caulk can be predicted
- Mass transfer models require partition and diffusion coefficients

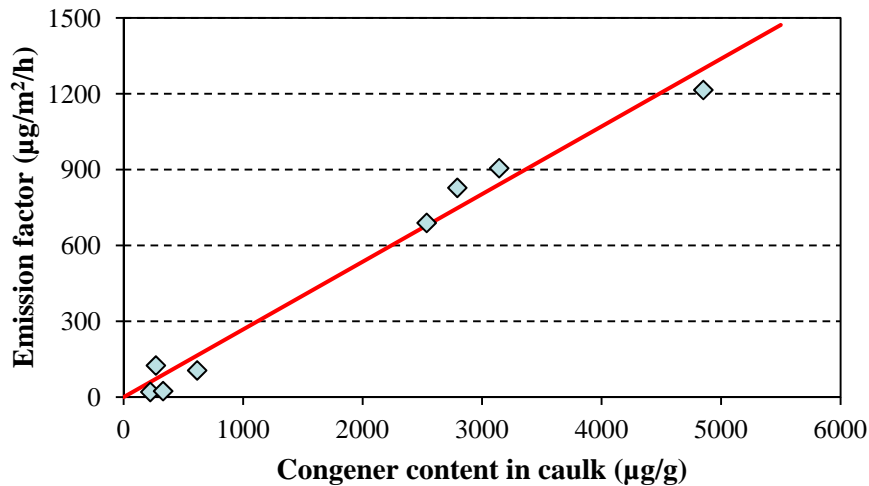
## ❖ Emissions from Light Ballasts

- PCB emissions from light ballasts are difficult to predict
- The emission rate is sensitive to temperature

## ❖ Use of the Emission Data

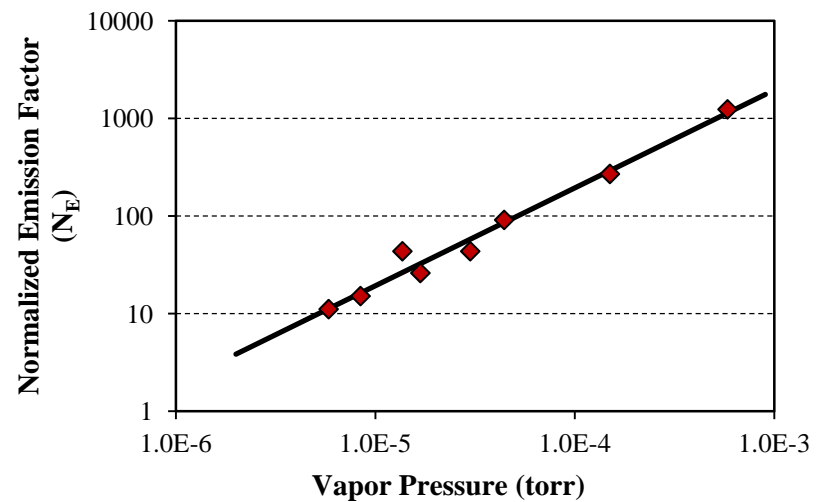
- Link the PCB content in primary sources and PCB concentrations in room air
- Rank indoor PCB sources by the data and empirical models
- Provide parameters for indoor contaminant models and for exposure models.

# Major Findings



For a given congener (e.g. #52), the emission factor is proportional to its content in the caulk

For a given congener the normalized emission factor is proportional to its vapor pressure



Normalized emission factor is the emission factor when the concentration in the source is 1000 µg/g

# Major Findings

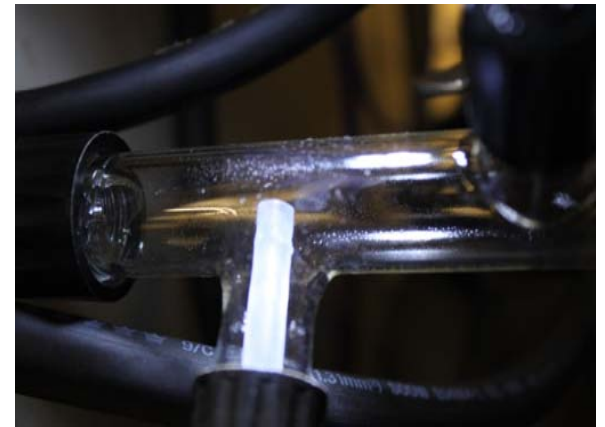
- ❖ One light ballast ruptured in the test chamber, causing sudden release of Aroclor 1242
- ❖ Existing PCB-containing light ballasts have reached or exceeded their designed life span. The failure rate will increase drastically near the end of their life.



**Ballast after the rupture**



**Expanded capacitor**



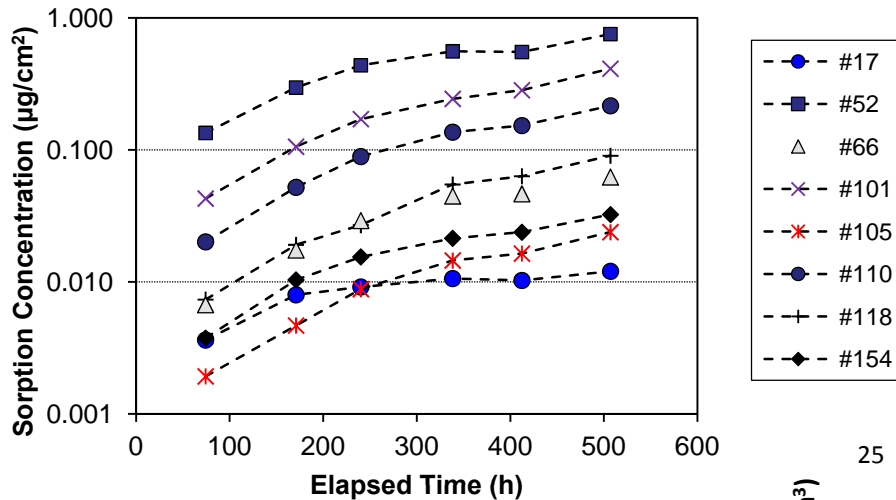
**Vapor condensation**

# Major Findings

## Transport to building materials and settled dust

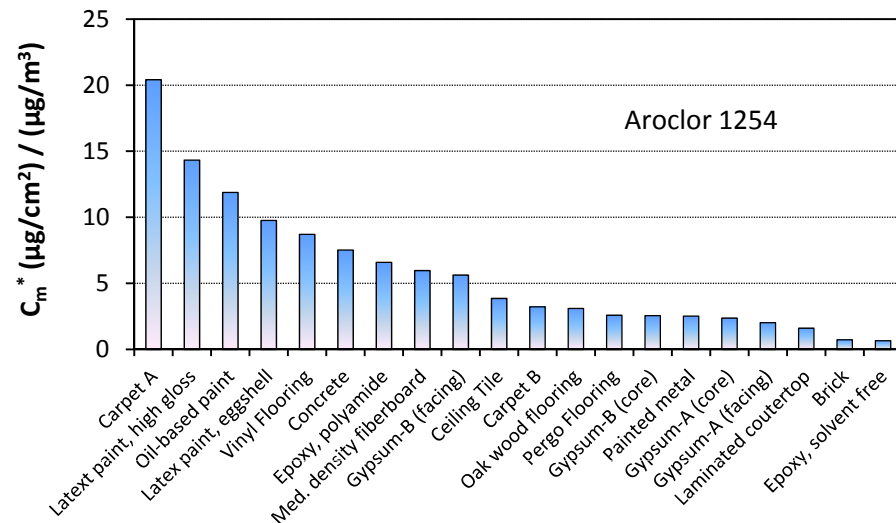
- ❖ A new experimental method for testing the sorption and subsequent re-emission of PCBs
- ❖ Settled dust as a special sink for indoor PCBs
- ❖ Rough estimates of the partition and diffusion coefficients by applying an existing mass transfer model to the chamber data.
- ❖ Sink strengths varied significantly from material to material
- ❖ Remediation plans should consider the potential effect of PCB sinks as secondary sources

# Major Findings



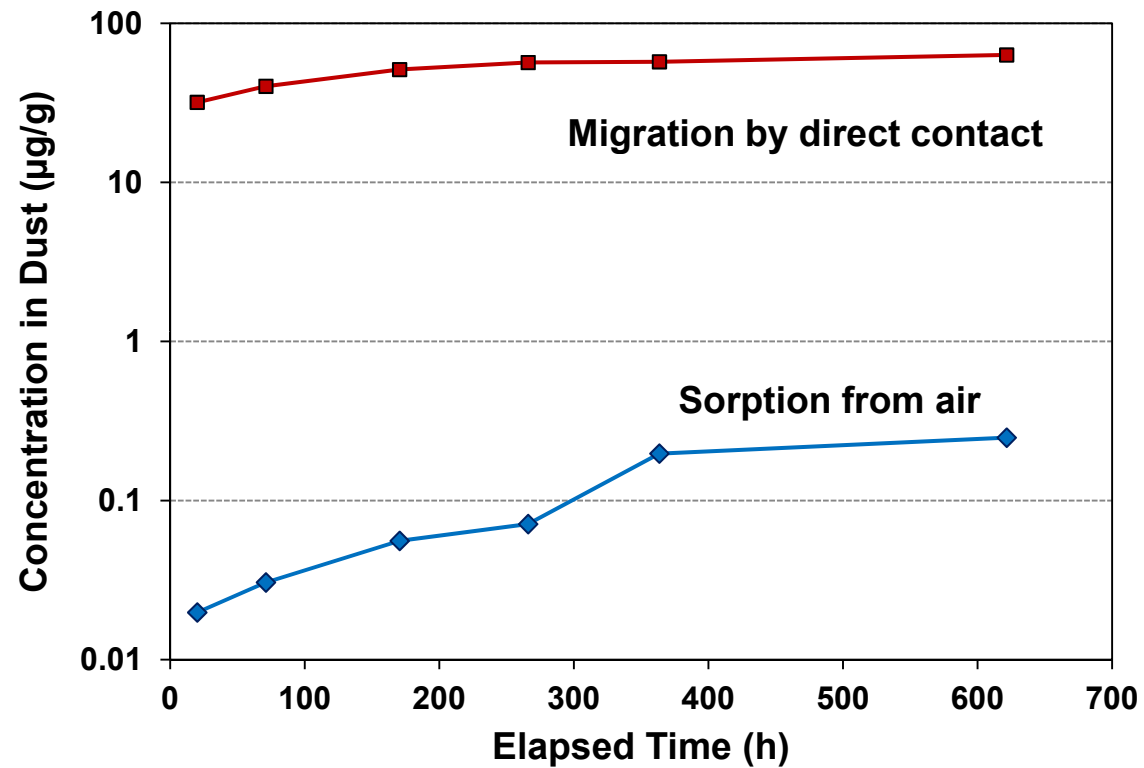
**Sorption concentration for concrete as a function of time (the legend show the congener IDs)**

**Normalized sorption concentrations ( $C_m^*$ ) for Aroclor 1254 for the materials ( $t \approx 250$  h)**



**Normalized sorption concentration is the sorption concentration when the air concentration is  $1 \mu\text{g}/\text{m}^3$**

# Major Findings



**PCB accumulation in settled dust**

# Major Findings

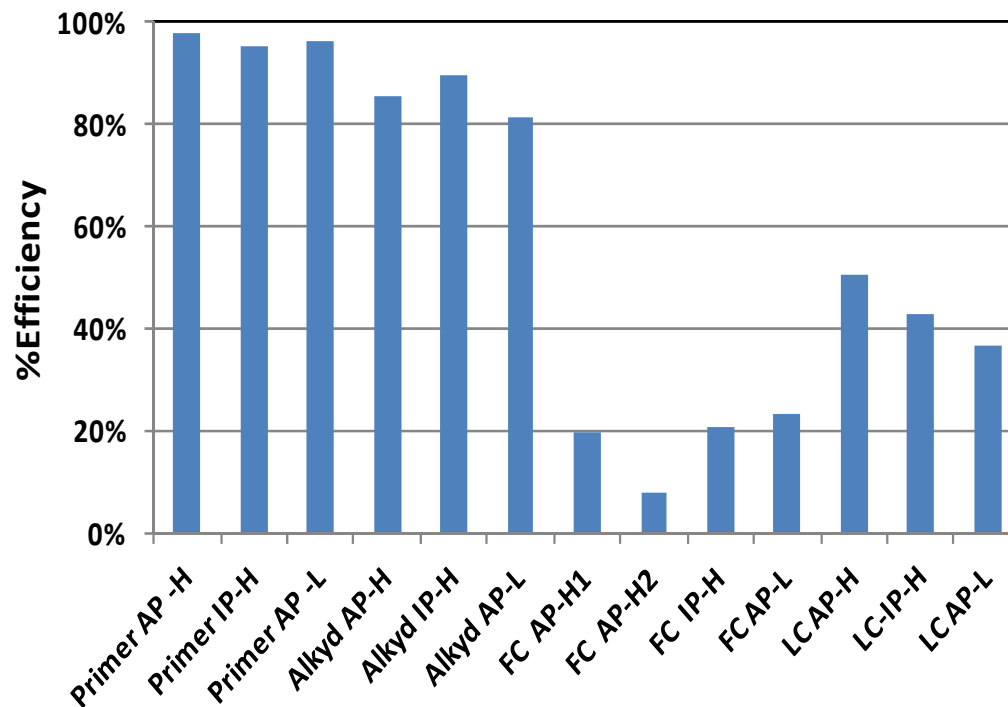
## Evaluation of the encapsulation method

- ❖ Encapsulation is suitable for sources with low PCB content
- ❖ The encapsulating ability is governed mainly by the partition and diffusion coefficients
- ❖ Selecting high-performance encapsulants is critical
- ❖ It is not feasible to encapsulate sources with high PCB content

# Major Findings

## Evaluation of an on-site PCB destruction method (AMTS)

- ❖ Effectively eliminate PCBs from paint at the level of several thousand ppm
- ❖ Limited penetration depths for concrete and caulk
- ❖ Multi-layer source models employed to predict the “bleed-back” of PCBs



**% Efficiency of AMTS method  
on different materials**

$$\% \text{ Efficiency} = (1 - C/C_0) * 100$$

**AP-active paste, IP-inactive  
paste, H- high PCB  
concentrations, L-low PCB  
concentrations, FC- field  
caulk, LC-lab-mixed concrete**



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# Limitations & Future Work

It was not our intention to collect and test samples that are statistically representative of the primary sources in U.S. building stock or to link the test results to the buildings from which the samples were collected.

## **The following are specific research limitations**

- ❖ This study was limited to laboratory testing only. The results are yet to be tested in the field.
- ❖ Only a few tests were conducted with a limited number of test specimens.
- ❖ It was not feasible to investigate all transport mechanisms in a single study.
- ❖ The values of the material/air partition coefficient and the solid-phase diffusion coefficient that we reported are rough estimates. The average relative standard deviations for the two parameters were 35% and 72%, respectively.

# Limitations & Future Work

## Recommended Future Work

- ❖ Further study should include developing methods for measuring the solid/air partition coefficients and solid-phase diffusion coefficients for PCB congeners in caulk and other building materials separately
- ❖ The effect of the composition of caulk and sealants on PCB emissions should also be investigated
- ❖ The newly developed experimental method for testing the sorption and subsequent re-emission of PCBs from building materials could be applied to other SVOC studies
- ❖ The correlation of the PCB concentration in the surface material and the concentration in the wipe samples is poorly understood. This data gap makes it difficult to link the wipe sampling results to the barrier models.



# Acknowledgements

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